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Assessing Decision-Making Skills in Electricity: Rasch Analysis

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Abstract: Decision-making is an essential 21st-century skill, and this is evidenced by the fact that the skill has increasingly gained attention in the current educational landscape. Accordingly, among the various competencies assessed by PISA, decision-making has been observed to be at the top of the list. This skill is particularly important, especially considering the fact that it provides college graduates with a competitive edge in the current workforce. Despite its significance, little work has been carried out to measure decision-making in the context of physics education using Rasch analysis. Therefore, this study aimed to explore the decision-making skills of prospective science teachers, with particular attention to differences based on gender and domicile. In order to achieve the stated objective, a quantitative study method was adopted, with the inclusion of 172 prospective science teachers who had received basic physics. Accordingly, data were collected using a paper-based test technique, which included six questions related to decision-making skills. The physics material utilized during the course of the study includes dynamic electricity, and in terms of the determination of validity and reliability, as well as item difficulty and differences in decision-making skills based on gender and domicile of the prospective science teacher, the Rasch measurement approach was adopted. The obtained results showed that no items could be reviewed based on gender and domicile of the observed prospective science teachers. However, a significant difference was found between the decision-making skills of participants based on gender. Following the observations, the decision-making skills of females were better than those of males, regardless of domicile. In conclusion, the decision-making skills instrument was observed to be valid and reliable. Additionally, the investigation possesses some implications for science educators in the aspect of determining differentiated physics learning designs that accommodate the abilities of students based on gender.

Keywords: *decision-making skills, gender, physics learning, prospective teacher, rasch analysis.*

Introduction

Decision-making skills are a very important requirement across diverse professions and have been observed to play an essential role in realizing citizen awareness of the dimensions of life and the development of sustainable education (Khishfe, 2012; León et al., 2020). Decision-making skills correlate with students' 21st-century skills (Erbas et al., 2025). This study contributes to the sustainable development goals of quality, inclusive, equitable, and gender-equal education (SDGs 4 and 5). Accordingly, theories related to decision-making have been applied across various disciplines, including education, medicine, computer science, mathematics, psychology, nursing, and physics (Kinskey and Zeidler, 2024; Sadeghi et al., 2024; Smoliński and Brycz, 2024; Tutticci and Huss, 2025; Erbas et al., 2025; Yang et al., 2024). As stated in previous studies, decision-making is an important 21st-century competence that needs to be practiced and developed by individuals. It often comprises complex analysis, an in-depth understanding of theory, and the application of concepts in the real world. Physicians, epidemiologists, educators, engineers, and poli-

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cymakers have shown interest in decision-making skills (Garg et al., 2023; Goosen and Steenkamp, 2023; Laka et al., 2022; Razaghpoor et al., 2024). Following the report of Orhan and Ataman (2024), accurate decision-making is correlated with both reflective and creative thinking dispositions and is considered a critical factor that can aid individuals in attaining success in the future.

Many studies have shown the importance of decision-making skills in various contexts. For instance, these skills have been found to possess a significant relationship with reasoning (Sakschewski et al., 2014), critical thinking (Wolcott and Sargent, 2021), scientific literacy (Spatz, Tampe, and Slezak, 2019), problem-solving on social scientific issues (Garrecht et al., 2020; Pietrocola et al., 2021), competence and mental health (Bavol'ár and Orosová, 2015), as well as regulating learning (Zhang and Hsu, 2021). In accordance with this, Gresch et al. (2017) found that decision-making strategies integrated with reflective thinking, the decision-making processes, and self-regulation elements were very beneficial in science, technology, society, and environmental education. Another study stated that decision-making skills could be improved through real-world and game-based learning, particularly within the context of nursing students (Vázquez-Calatayud et al., 2024).

Numerous investigations have been conducted across various fields with the aim of developing clinical decision-making instruments within several countries (Lauri and Salanterä, 2002). The subject matter has also been examined within the domain of science education, particularly in countries such as Germany, where the competence was associated with environmental issues (Garrecht et al., 2020). Furthermore, the decision-making abilities and styles of junior high school students have been explored (Novianawati and Nahadi, 2015). Regardless of the diverse reach, these studies often fall short in addressing the skills in a more advanced way among undergraduates. Assessing decision-making skills among university students is crucial, considering the fact that it not only emphasizes the developmental progress of the students but also provides invaluable insight for improving curricula. It is also important to state that the measurements that will be obtained from such assessments could offer educators a clearer understanding of student abilities while equipping students with the skills necessary to thrive in the workforce. This study, in particular, adds to the growing body of knowledge by examining decision-making skills within the context of physics learning among prospective teachers in higher education.

Literature Review

Decision-Making Skills in Physics Learning

Current educational policies require a combination of technology, instructional design, and decision-making (Mettas, 2011). The Industry 4.0 era requires graduates with strong decision-making skills (Torres et al., 2023). Decision-making skills are necessary for success in today's professional landscape (Erol et al., 2016). This is reinforced by the opinion of Olmstead et al. (2023), who stated that physics learning is strengthened by knowledge and the choice to study the subject. Physics learning must be enriched with complex ethical decision-making skills to support students who intend to build future careers outside the field. Decision-making skills fall within cognitive development and have become a significant focus in scientific studies. Therefore, physics learning is highly relevant to scientific inquiry, decision-making, and the habit of solving complex problems in physics learning.

Higher education plays a crucial role in preparing students to compete globally. Therefore, higher education curricula need to be designed to integrate decision-making skills into every department within the institution, including physics. As stated in previous studies, scientific decision-making practices are closely related to learning the processes and practices of science (Holmes et al., 2020). For example, laboratory experiments in physics are typically designed to stimulate students to solve real-world problems, select the best solution, determine tools and materials, and design practical procedures. Decision-making skills can be practiced during traditional physics laboratory activities. Generally, students' decisions during practical activities include the equipment used, the amount of data to collect, and how to analyze experimental data. Physics learning encourages students to think critically and make decisions. According to Vygotsky's constructivist theory, students actively construct knowledge through experience during learning activities.

Decision-making style is a learned and habitual response pattern that individuals typically exhibit when facing problems. Decision-making skills are related to students' cognitive styles. Decision-making styles are intuitive and rational (Abubakar et al., 2019). Intuitive decision-making is a right-brain decision-

making style that prioritizes feelings over facts. Intuitive decision-making can be based on experience or previous knowledge (metacognitive). Meanwhile, the rational decision-making process is characterized by identifying problems, generating possible solutions, selecting feasible solutions, and implementing and evaluating the chosen solutions. Rational decision-making is influenced by knowledge management.

The success of physics learning can be measured using assessment instruments. One physics learning instrument is designed to assess students' decision-making skills. This approach suggests that after students have mastered physics theory and engaged in appropriate practice, the results obtained from solving problems should be measured through decision-making assessments. Electricity is a crucial physics topic related to everyday life applications and requires problem-solving. Therefore, the problem-solving process requires complex knowledge and appropriate decision-making skills. This aligns with Jeong et al.'s (2024) opinion that students must be trained to solve complex problems and improve their physics knowledge through learning designs and assessments that measure decision-making skills.

Studies show differences in decision-making skills between males and females (Villanueva-Moya and Expósito, 2021). This suggests that gender stereotype threat can influence the decision-making processes of both genders and has important implications for educational decision-making and gender interventions. This explanation is supported by the fact that men are often more likely to take risks and be selective in achieving their goals through individual decisions. At the same time, women are more conservative (Lozano et al., 2017). Individual decision-making skills are influenced by conceptual mastery, psychological conditions, and gender differences (Sokol et al., 2019; Byrne et al., 2020; Villanueva-Moya and Expósito, 2021).

Rasch Analysis

George Rasch, a Danish mathematician, developed Rasch measurement. Rasch measurement is based on the interaction of items, individuals, and probability estimates. Rasch analysis is used in research to overcome the limitations of classical test theory. In this study, Rasch analysis is used for objective measurement, which includes examining the relationship between individuals and items related to decision-making skills. Previous studies have explored the decision-making skills of physics (Holmes et al., 2020) and chemical engineering students through parametric data analysis (Burkholder et al., 2021). However, after reviewing the existing literature, no publication has adopted Rasch analysis to assess decision-making skills in electrical engineering from the perspective of gender and domicile. Rasch analysis has advantages, including the ability to provide consistent and independent measures for samples and items, ensure unidimensionality, assess model fit, and detect differential item functioning (DIF) based on gender, domicile, and clarity of interpretation (Linacre, 2002). Considering the gap, this study aimed to address three key questions, including,

1. How do the validity and reliability of the electricity decision-making skills test hold up based on Rasch parameters?
2. Is there a DIF in the test based on gender and domicile?
3. What are the observed differences in the decision-making skills of students when categorized by gender and domicile?

Materials and Methods

Design, Participant, and Procedure

The present study adopted a quantitative method, with a sample size of 172 students from state universities. The sample comprised 75 male students (43.6%) and 97 female students (56.4%), all of which were science education students who had completed basic physics courses. Accordingly, the students voluntarily answered the test questions over a 90-minute session using a traditional paper-and-pencil format. Through the test, information regarding the gender and place of residence of the study participants was collected. Table 1 presents the demographic profile of the participants.

Table 1. *Demographic profiles in this study*

Demographic		Frequency	Percentage (%)
Gender	Male	75	43.6
	Female	97	56.4
University type	Public	172	100.0
Study programme	Biology Education	102	59.3
	Science Education	70	40.7
Living place	Urban	64	37.2
	Rural	108	62.8

Instruments

The decision-making skills instrument consists of six essay-based questions, with responses evaluated using a rubric. These questions focused on electrical concepts since it is a topic closely connected to the everyday experiences of students. The data collection included administering the test, which students completed within 90 minutes, and respective responses were subsequently scored using a rubric and converted into a scale ranging from 1 to 3. Electrical circuits are crucial elements of physics and are closely related to students' daily lives. However, students have not yet fully mastered the concept of simple electrical circuits (Burde et al., 2022; Burde and Wilhelm, 2020). Therefore, prospective science teachers must have a solid understanding of electricity. The rationale for selecting electrical circuit problems is to train students' thinking skills to solve electrical problems. Students are trained to make decisions based on the electrical phenomena presented in the problems. Furthermore, the physics curriculum in universities recommends that prospective science teachers be trained in decision-making skills (Montgomery et al., 2024).

Table 2. *Electrical topic test questions based on decision-making skills indicators*

Decision-making Indicator	Item
Analyze the existence of several possible alternative answers along with the risks that may arise (DM1)	You are tasked with creating a simple electrical circuit that requires two resistors connected in series. You have three alternative resistors: R_1 = 10 Ω and R_2 = 30 Ω, R_1 = 20 Ω and R_2 = 30 Ω, or R_1 = 30 Ω and R_2 = 40 Ω. a) Select the correct combination of resistors to produce a total resistance of 50 Ω! b) Provide arguments regarding the possible risks of using each resistor combination.
Evaluating the inherent decision-making process (DM2)	An electrical circuit consists of a 9-volt battery and a 6 Ω resistor. A student measures the current in the circuit as 1.5 A. The student uses Ohm's law to calculate the voltage across the circuit. The student obtains a result of 4.5 volts. Evaluate the student's decision!
Analyze the relationship between problems and existing rules or concepts (DM3)	Anwar was asked to design an electrical circuit with a 12-volt battery, a 6 Ω resistor, and a 3Ω lamp. Anwar wanted to determine the current flowing in the circuit and the power consumed by the lamp. Questions: a) How can one articulate the voltage, resistance, and current relationship? b) What is the calculated current flowing through the circuit? c) How do we determine the power the lamp consumes in the circuit? d) In what ways does Ohm's Law connect to the current and power calculation from this circuit?
Understanding the basis of irrelevant decision-making (DM4)	Agus has an electrical circuit consisting of one battery as a voltage source, two lamps (lamps A and B), and one switch. Only lamp A lights up when the switch is pressed, while lamp B remains off. a) Describe the steps to understand why only lamp A lights up when the switch is pressed! b) Identify irrelevant decisions or assumptions in the circuit analysis!
Integrating related beliefs and values (DM5)	You are designing an electrical circuit consisting of a 12-volt battery, a 4-Ω lamp, and a resistor. There are two resistors to choose from: R_1 = 6 Ω and R_2 = 10 Ω. Determine which resistor you will use in the circuit! Provide arguments based on your beliefs and related values!
Detecting errors in answer construction (DM6)	Anwar has an electrical circuit consisting of a 9-volt battery and two parallel resistors, R_1 = 4 Ω and R_2 = 6 Ω, respectively. Anwar was asked to calculate the total current flowing in the circuit. Anwar's answer, for the total current obtained, is 0.9 A. Anwar explained that the total current in the circuit can be calculated by adding the resistances of R_1 and R_2, then dividing the voltage by the total resistance. Based on Anwar's answer, detect the error in Anwar's answer!

Table 2 presents the framework for the electricity decision-making skills instrument. In line with the study by Bavol'ár and Orosová (2015), the instrument is built upon six indicators of decision-making skills namely analyzing the presence of multiple possible alternative answers along with potential risks (consistency in risk perception), examining the relationship between the problem and established rules or concepts (recognizing norms), identifying errors when formulating answers (resistance to framing), understanding the rationale behind irrelevant decisions (resistance to sunk costs), integrating related beliefs and values, as well as evaluating inherent decision-making process.

Data Analysis

WINSTEPS software version 3.73 (Linacre, 2020) was utilized for Rasch analysis, while SPSS version 22 was adopted to describe the quantitative data from the demographic profiles of the participants. The analysis focused on various aspects such as the validity and reliability of both items and participants, item measures and fit criteria, person fit, Wright map, Differential Item Functioning (DIF) based on gender and domicile, as well as Independent t-tests and one-way ANOVA. During the course of the analysis, several important Rasch indicators were examined, including unidimensionality, item and person separation indices, item and person reliability, as well as infit and outfit MNSQ values, all of which were considered essential for evaluating decision-making skills. Unidimensionality is an important metric that ensures the instrument measures what it is supposed to measure. To meet this criterion, the raw variance must exceed 30%, and the unexplained variance of the first contrast should ideally be less than 15% (Laliyo et al., 2021). For reliability, a Cronbach's Alpha value above 0.60 was considered acceptable (Soeharto et al., 2024; Taber, 2018) and in terms of separation indices, a value of two or more signifies sufficient distinction between the ability of a person and the difficulty level of the items (Linacre, 2020). As stated in a previous study, a higher separation index signifies more precise differentiation (Pilatti et al., 2015). Following separation indices, item, and person validity were assessed using fit criteria, with acceptable ranges for the mean square (MNSQ) values of outfit and infit being between 0.5 and 1.5. Additionally, acceptable ranges for Outfit Z-Standard values were between -2.0 and +2.0, and for Point Measure Correlation (PTMA), between 0.4 and 0.85 (Boone et al., 2014).

Results

Validity

The validity of the decision-making skills instrument, which was determined using item and person parameters generated from the Rasch analysis, is detailed in Table 3. As observed, the outfit and infit MNSQ values for both persons and items showed satisfactory fit validity. The mean outfit MNSQ for persons was 0.87, and the infit MNSQ was 0.79, both within the acceptable range of 0.5 to 1.5, accompanied by a positive Point Measure Correlation (PTMA) value. Similarly, the mean outfit MNSQ for items was 0.87, and the infit MNSQ was 1.01, also meeting the fit validity criteria with a positive PTMA value (Boone et al., 2014). The person separation index obtained was 2.78, and this suggested that the participants could be grouped into more than two distinct (heterogeneous) categories based on the respective abilities of the students. Meanwhile, the obtained item separation index of 5.91 showed that the test items effectively differentiated between the decision-making skills of the students. The construct validity of the instrument was further confirmed through its unidimensionality, with 60.6% of raw variance explained by the measure, showing that the instrument reliably assessed the skills of the observed demographic (Ubaidillah et al., 2022). The unexplained variance was 12.9%, which is below the 15% threshold, further supporting the unidimensionality of the instrument.

Table 3. *The summary statistics based on Rasch's measurement*

	Persons	Item
N	172	6
Mean Measure	2.69	0.0
Max. Measure	7.40	2.16
Min. Measure	-5.21	-2.61
SD	4.36	1.41
SE	0.33	0.63
Mean Outfit MNSQ	0.87	0.87
Mean Infit MNSQ	0.79	1.01
Separation	2.78	5.91
Reliability	0.89	0.97
Cronbach's Alpha	0.85	
Log-Likelihood Chi-squared (χ2)	813.08 (df= 799)	
Probability	0.3569*	
Unidimensionality		
Raw variance explained by Measure	60.6%	
Raw unexplained variance	39.4%	
Unexplained variance 1st Contrast	12.9%	

*Normally distributed

In Table 4, the item measures and fit criteria are presented to confirm the validity of the fit at the item level. The item measure values were observed to be within the range from -2.61 to 2.16 logits. Accordingly, the infit and outfit MNSQ values ranged from 0.80 to 1.33 logits, and from 0.61 to 1.31 logits, respectively. These values fall within the acceptable range of 0.5 to 1.5 for fit validity (Infit-Outfit MNSQ), implying that the items met the criteria for fit validity. It is also important to state that the Z-Standards (ZSTD) outfit values ranged from -1.35 to +1.00, implying the students comprehended all items without any significant misconceptions.

Table 4. *Item measure and fit criteria*

Item Number	Measure	Infit MNSQ	Outfit MNSQ	Outflt ZSTD	PTMA
DM1	-0.12	0.80	0.61	-1.35	0.75
DM2	2.16	1.33	1.31	1.00	0.81
DM3	0.33	0.86	0.66	-1.21	0.82
DM4	0.48	0.97	0.77	-0.76	0.51
DM5	-0.24	0.80	0.62	-1.34	0.76
DM6	-2.61	1.28	1.23	0.69	0.77

Reliability

The reliability of the decision-making skills instrument was determined using Cronbach's alpha value, as shown in Table 3. The item reliability was observed to be exceptionally high at 0.98, and the person reliability was strong, with a value of 0.89. As stated in a previous study, Cronbach's alpha of 0.85 confirms that the decision-making skills instrument is reliable (Taber, 2018). Furthermore, the p-value of 0.3569, which is greater than 0.05, showed that the Rasch model provides a good fit for the data analyzed.

Fit Item Analysis

Figure 1 presents the graph of the Bubble fit item analysis carried out during the course of this study. Based on predefined standards, the larger the circles in the diagram, the greater the margin of error, indicating a challenge in distinguishing the abilities of students. However, the smaller the circle, the smaller the standard error, implying that the item is more effective at differentiating student abilities (see Figure 1). In terms of difficulty, items located higher on the scale were observed to be more challenging, while items DM1, DM3, and DM5 are clustered closely together within the fit region, showing that these items were easier but still corresponded properly with the model. Item DM4 is also in the fit area

but presents a higher level of difficulty compared to DM1, DM3, and DM5. On the other hand, DM6 fell into the underfit region, reflecting that the responses to this item do not correspond with the expectations of the model. Item DM2 is also located in the underfit area, although it is positioned closer to the fit line compared to DM6.

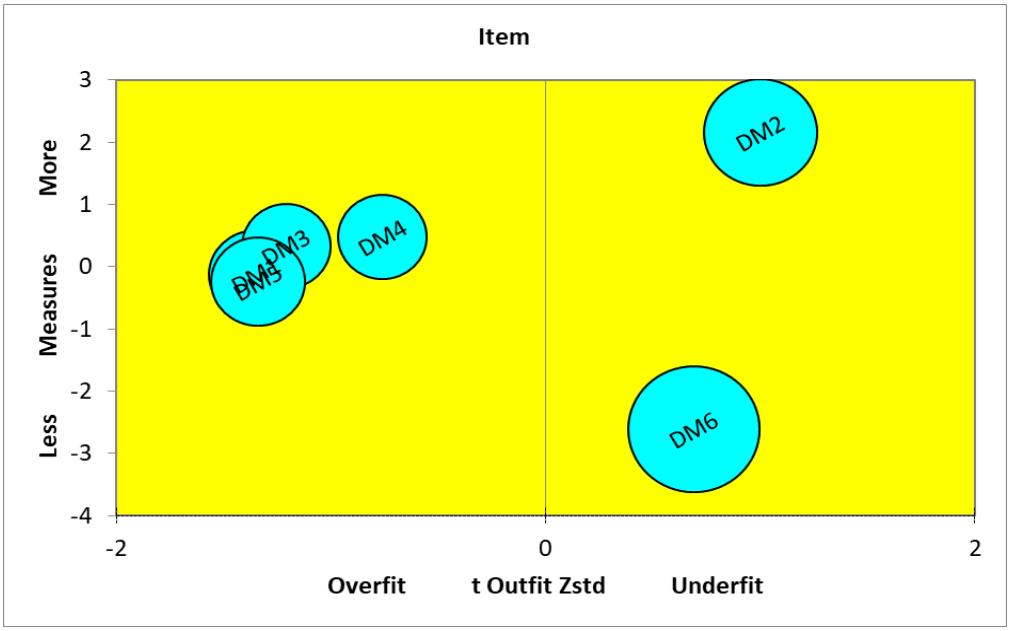

Figure 1. Bubble fit item analysis

Wright Map

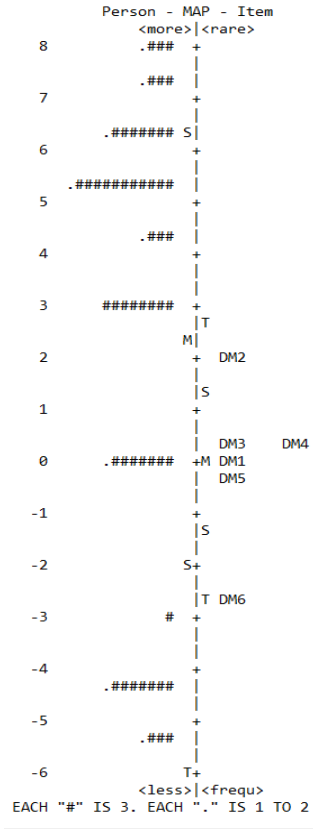

Figure 2. Item-person map

Wright's map was used to gain valuable insights into the difficulty levels of the decision-making skills items considered in this study. The map showed a variety of items, ranging from those that students find challenging to those that are easier to tackle. Typically, items that present significant difficulty can guide teachers in identifying areas where students struggle. This information allows educators to tailor respective instructional strategies and implement targeted interventions to address these weaknesses effectively. By utilizing the insights gained from the Wright map, teachers can enhance respective teaching methods and support students in improving inherent decision-making skills.

From Figure 2, it can be seen that item DM6, which focuses on detecting errors in answers, was perceived as very easy by most students. Dissimilar to this, item DM2, which pertains to self-evaluation, was the most challenging for the students. The participants performed generally well on items DM1, DM3, DM4, and DM5. The Wright map served as a diagnostic tool, emphasizing that students need to enhance performance on item DM2. This information allows teachers to provide targeted remediation for those who struggle with the item. Within this context, educators can emphasize self-evaluation training in decision-making by incorporating case studies and practical laboratory activities to develop students' self-assessment skills.

Differential Item Functioning (DIF) Analysis Based on Gender

DIF analysis was adopted to examine potential gender-based biases that may influence decision-making skills. According to Boone et al. (2014), DIF analysis is effective in identifying participant bias at the item level, allowing for a proper understanding of the manner in which background variables may affect responses to specific items.

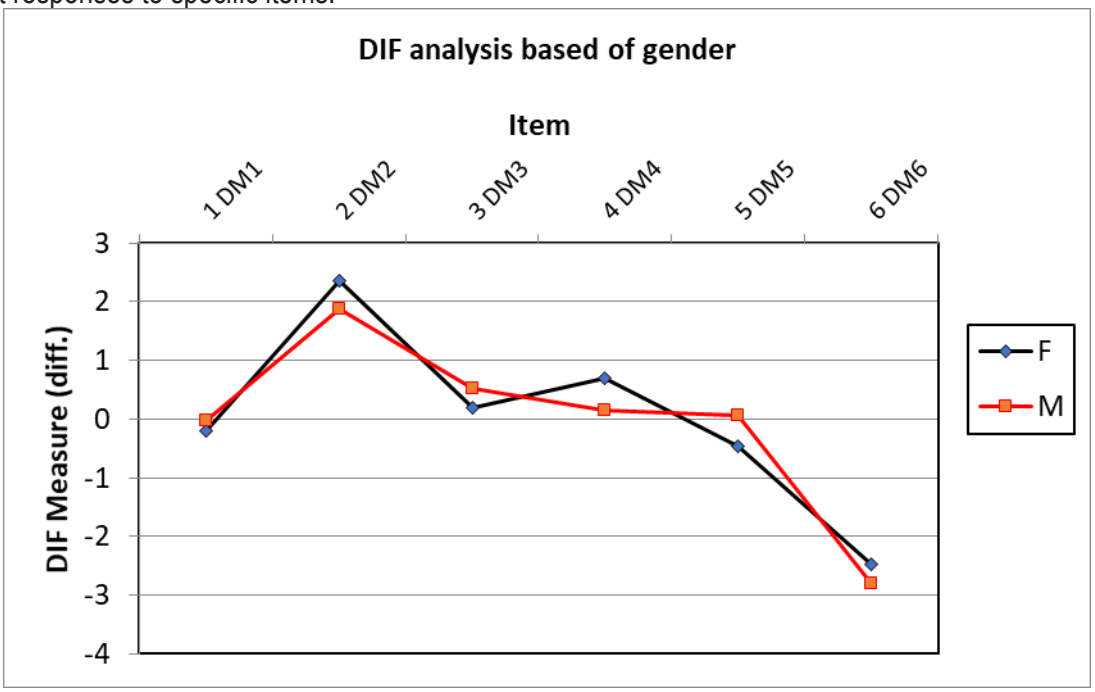

Figure 3. DIF based on gender

Figure 3 presents the graphical representation of the difficulty levels of the items, showing that DM2 was the most challenging, followed by DM4, DM3, DM5, and finally DM1. Based on observation, DM2, DM4, and DM6 posed more challenges for female students compared to the males. However, female students showed stronger performance on items DM1, DM3, and DM5 than male students. Table 5 presents the probability values for all items, which were greater than 0.05. This finding shows that none of the items exhibit gender bias.

Table 5 . *Differential item functioning based on gender*

Item Number	Person Class	Summary Dif Chi-Square	Prob.
DM1	2	0.203	0.652
DM2	2	1.078	0.299
DM3	2	0.708	0.400
DM4	2	1.845	0.174
DM5	2	1.826	0.177
DM6	2	0.326	0.568

Differential Item Functioning (DIF) based on living place

During the course of this study, DIF analysis was instrumental in identifying whether the decision-making skills items had any form of bias related to the geographical location of the observed prospective science teachers. This analytical approach allows for the examination of item bias based on various participant background variables (Boone et al., 2014). Furthermore, according to the established DIF criteria, a probability value greater than 0.05 signifies the absence of significant bias in the items (Soeharto et al., 2024).

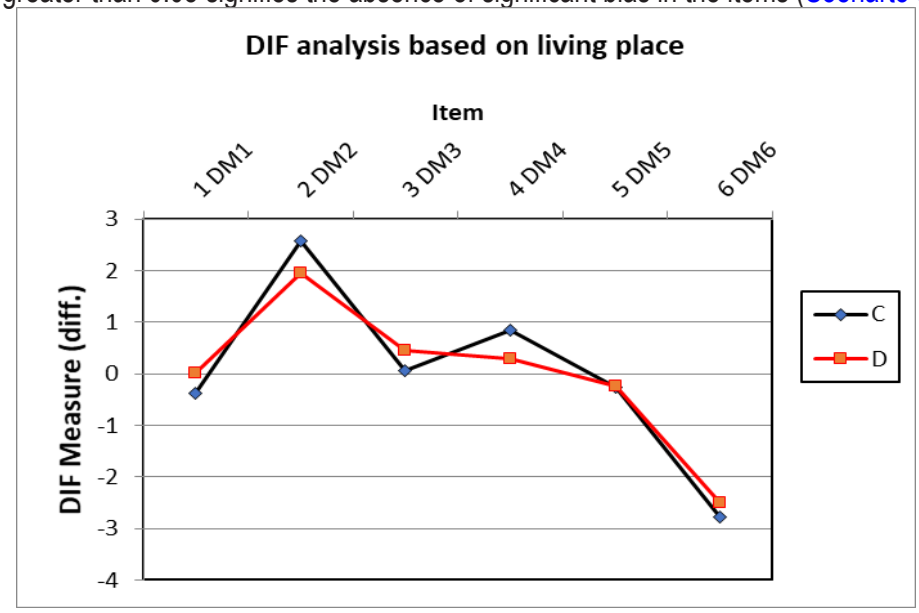

Figure 4. DIF based on domicile

Figure 4 shows that students residing in urban areas (C) performed better on questions DM1, DM3, and DM6 compared to those residing in rural areas (D). However, urban students were observed to face greater challenges with items DM2 and DM4 than those living in the village. Interestingly, for item DM5, students from both areas showed comparable abilities in tackling the question. Table 6 presents the item probability values, which can be used to further assess any potential bias arising from the differences in abilities between urban and rural students.

Table 6. *Differential item functioning based on domicile*

Item Number	Person Class	Summary Dif Chi-Square	Prob.
DM1	2	0.845	0.358
DM2	2	1.295	0.238
DM3	2	0.932	0.335
DM4	2	1.749	0.186
DM5	2	0.005	0.943
DM6	2	0.242	0.623

Table 6 shows that the probability value of the items is greater than 0.05. This implies that all the items did not contain domicile bias.

T-test and ANOVA

Table 7. *The Independent t-test and one-way ANOVA for comparing student decision-making skills between gender and domicile*

Background factor	Group	Mean (SD)	df (df1, df2)	Mean Difference	t-test	F-test	p
Gender	Female	3.30(4.32)	1, 159	1.39	2.09	4.37	0.038
	Male	1.90(4.29)					
Living Place	Urban	3.27(3.92)	1, 148	0.92	1.38	1.90	0.169
	Rural	2.35(4.57)					

The obtained results in their entirety showed that female students possessed superior decision-making skills compared to males, with an average difference of 1.39 logits (see Table 7). The significance value of 0.0385, which is less than 0.05, further confirms a statistically significant difference in decision-making skills between the two genders. This conclusion is further supported by the F-test result of 4.37 and the t-test result of 2.09, reinforcing that the observed difference was not merely due to chance.

In terms of geographic differences, students from urban areas showed better decision-making skills than residents in rural areas, with a difference of 0.92 logits (see Table 7). However, the significance value of 0.169, which exceeds 0.05, implies that this difference was not statistically significant. Considering the implication, no meaningful distinction in decision-making skills was observed based on place of residence.

Discussions

Using the Rasch model as an analytical approach and a form of fair assessment practice. Educators can provide optimal learning services by measuring students' cognitive abilities. Research results show that the Rasch analysis approach measures cognitive abilities (Soeharto and Csapó, 2022). The Rasch model can differentiate the analysis of students' thinking abilities (Chin et al., 2022), distinguish students' interests in learning particle physics (Zoechling et al., 2022), cognitive diagnostics (Chin et al., 2022), critical thinking skills (Kassiavera et al., 2024; Suwita et al., 2023), and analytical thinking in physics learning (Nurussaniah et al., 2025). Therefore, using the Rasch model in measuring cognitive learning outcomes is highly recommended for application in science learning.

The findings of this study show that the physics decision-making skills instrument developed had both validity and reliability. The study emphatically contributes to the measurement of decision-making skills through the Rasch approach and underscores the importance of comprehensive assessments in various contexts. Accordingly, by analyzing item and person characteristics, the exploration provides critical insights that can aid in the development of valid and reliable measurement instruments.

The results of the ANOVA test presented in Table 7 showed that female students had superior decision-making skills compared to male students, with psychological and social factors playing a significant role in explaining this difference. The finding is also supported by previous studies, where it had been suggested that females tend to be more meticulous when making decisions, often considering a multitude of variables and risk factors (Lozano et al., 2017). Research results indicate differences in decision-making skills between males and females (Thi et al., 2022). This finding is supported by studies that show that female students experience greater improvement in decision-making than male students (Khazen et al., 2025). This tendency may be associated with the greater capacity for empathy often found in females, which enhances the decision-making processes of the demographic. Moreover, social and emotional factors, as well as creative and critical thinking, have been observed to be integral to decision-making skills (Abraham et al., 2014). Studies have shown that reasoning and learning environment can influence sustainable decision-making (Khazen et al., 2025; Tutticci and Huss, 2025). Previous investigations have also indicated that during conceptual expansion, males engage areas of the brain associated with semantic cognition, rule learning, and decision-making, while females tend to activate regions related to language processing and social perception. This neurological difference further explains the unique approaches that both genders bring to decision-making.

In accordance with this, the skills of both females and males were observed to be influenced by prevailing gender stereotypes. The obtained results also showed that females were increasingly inter-

ested in studying physics, a field historically associated with males (Eren, 2022). This shift signifies a growing acknowledgment of equality between genders in the realm of science. In line with a previous exploration, the present investigation advocates for gender equality in all educational spaces, emphasizing the need to build scientific identities through intersectional perspectives, visibility of male and female scientists, and gender mainstreaming in scientific production (Buenestado-Fernández et al., 2024). This is particularly important, especially considering the fact that gender bias has been shown to hinder skill development, creating significant gaps across various fields, particularly in STEM disciplines (Barth et al., 2022). However, recent trends suggest that more females are pursuing careers in science, technology, and mathematics (Msambwa et al., 2024). This can be achieved by cultivating a science learning environment that prioritizes gender equality, thereby paving the way for a more inclusive and equitable future in the scientific community.

A study recommends gender mainstreaming in higher education to achieve sustainable development goals (Kataeva et al., 2025). Universities can be influential in promoting gender equality, diversity, and inclusion (Rosa and Clavero, 2022). However, research findings indicate that gender-responsive physics teaching remains limited (Atanasova et al., 2023). This aligns with studies showing that the avoidance of women in physics is a barrier to social progress (Bezen and Derman, 2025). The gender gap is characterized by the continued underrepresentation of women in STEM (Cheryan et al., 2025). Therefore, gender-responsive physics teaching and learning are highly recommended for prospective teachers (Atanasova et al., 2024). Gender-equitable education in higher education for students can be implemented through collaborative project participation, case studies, field trips, and didactic teaching delivery (Condron et al., 2023). Decision-making-based learning design begins with identifying problems, selecting optimal solutions, listing potential possibilities for problem solving, gathering information for problem solving, and analyzing plans (Condron et al., 2023).

When students face decision-making situations, they use intuition, recall previously learned physics concepts, and use patterns to solve problems. Typically, when students encounter complex problems, inherent cognitive processes essential for problem-solving are engaged (Jeong et al., 2024). A good understanding of various concepts enables individuals to analyze situations more effectively, consider a range of alternatives, and evaluate the consequences of the available options. In this regard, further studies are warranted to investigate whether the mastery of physics concepts differs between males and females and how this may significantly impact the physics decision-making skills of each gender. Accordingly, the observations made from the ANOVA test, as presented in Table 7, showed that no significant difference in decision-making skills existed between students residing in urban areas and those in rural areas. These findings are inconsistent with previous investigations, where it has been suggested that socio-demographic factors, particularly place of residence, significantly influence decision-making abilities (Clarke et al., 2024). For instance, Nasmilah et al. (2024) have shown that individuals in rural areas often adhere more closely to cultural norms, and this can impact respective decision-making processes. However, the current study reports that students living in urban and rural environments have similar access to education, resources, and technology, as well as social and cultural conditions.

Education that prioritizes equality between urban and rural students can build a high-quality education system (Guo and Li, 2024). Implementing a school curriculum that is equitable in urban and rural areas has the potential to provide equitable educational opportunities. Teachers can provide equitable physics teaching services to students through experimental learning, inquiry (Gao et al., 2025), group discussions, and decision-making exercises through gamification (Krishnamurthy et al., 2022). Furthermore, teachers with equal competence in urban and rural areas play a role as facilitators who practice decision-making skills. Research findings show no differences in students' decision-making skills between urban and rural areas. This implies that all students, regardless of location, have the potential to develop strong decision-making skills.

Rasch-based decision-making skills instruments can be adopted for biology, chemistry, and environmental courses. Measurement using the Rasch approach not only accurately measures student abilities but also considers psychometric aspects such as validity and reliability. Meanwhile, educational technology is currently developing very rapidly. Decision-making skills instruments can be integrated into digital and classroom-based formative assessments. Studies show that measuring physics thinking skills using the Rasch model approach can be done using a web-based CAT (Zakwandi et al., 2024). Educators can access the assessment results comprehensively and in real time. This allows physics teachers

to follow up on individual abilities quickly and accurately. Therefore, integrating Rasch-based decision-making skills instruments into the classroom can support more adaptive and personalized learning and technological developments.

Conclusions

In conclusion, the results of this study have contributed to the understanding of the interaction of test items and individuals on decision-making skills. The developed electrical decision-making skills test instrument met the requirements of validity and reliability. Therefore, this instrument can be used as an assessment tool. The developed test items were free from bias. Females significantly outperformed males in decision-making. Furthermore, prospective science teachers from urban and rural areas had comparable decision-making skills. This study provides practical recommendations for gender mainstreaming in higher education for stakeholders. Furthermore, teachers design strategies that accommodate gender differences and facilitate an inclusive learning environment. Teachers are advised to implement Rasch-based assessment to provide fair assessments. The Rasch model approach can help teachers identify students' specific needs and enable them to design appropriate remedial and enrichment programs. Future studies should explore the Rasch approach to measure students' decision-making skills more comprehensively, considering variations in decision-making styles, other physics topics, and integrating Rasch with technology.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, B.S., M.U., P.M., W. and H.; Resources, B.S., M.U., P.M., W., and H.; Methodology, M.U., W., and B.S.; Software, M.U., P.M., W., and B.S.; Formal Analysis, B.S., M.U., P.M., W., and H.; Writing – original draft, B.S., M.U., P.M., W., and H.; Writing – review & editing, B.S., M.U., P.M., W., and H. All authors have read and agreed to the published version of the manuscript.

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